Fundamental Physics on the Principle of Relativity

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Abstract

This article investigates the physics logic of the principle of relativity for particle dynamics. Through the analysis of causal corresponding in dynamics, the reason why the puzzle of inertial force and inertial reference frame exists in Newtonian mechanics is uncovered, and the conclusion is that the causal corresponding of the reference frame is neglected in the formula of particle dynamics. The dynamics property of the reference frame should be attributed to the reference object. At the same time, the reference object and the object being investigated should be put on an entirely equal status. Therefore, a new particle dynamics equation that is not affected by the inertial reference frame and keeps invariant in all translational frames of reference is introduced. As for the rotating reference frame, on the one hand, the nature of inertial forces has been revealed as the mass-ratio weighted real force acting on the reference object. So the physics effect of the gravitational force is not equal to that of the inertial force. On the other hand, in the spirit of causal corresponding, the physics of rotating reference frames must contain the dynamics properties of four non-coplanar reference objects. Hence it is difficult to be reconstructed into a concise formula. In this sense, this article also proposes that Einstein's principle of general relativity is not credible. The key point of the extension of the dynamical principle of relativity is to ensure the causal correspondence of reference object(s) on both sides of the dynamical equation.

Keywords: Particle dynamics; Inertial force; The principle of relativity; Reference object

1 Introduction

The dynamical principle of relativity is the basic property of dynamics, which represents the scope of application of the dynamics equation. In this applicable scope, the dynamics equation is still valid under the premise that its mathematical form and physics definition remains unchanged.

In Newtonian mechanics, the principle of relativity for particle dynamics is the Galilean principle of relativity[1, 2]. This principle states that the laws of classical mechanics are mathematically unchanged in any inertial reference frame. In other words, all inertial frames of reference are equivalent (equal weight). Newton's second law can only be applied to inertial frames of reference(here the inertial reference frame is denoted by Σ, and the investigated moving object or particle is denoted by p):

$$\boldsymbol{F}|_p = m_p \boldsymbol{a}|_{p-\Sigma}. \tag{1}$$

The puzzle, however, is that Newton's second law is only applicable in inertial reference frames, but the inertial reference frame is defined in terms of Newton's first law. That is, in a reference frame, if an object can always remain relatively static or uniform linear motion without interaction, then the reference frame is inertial. The condition to define the inertial reference frame is substantively included in Newton's second law. Therefore, on the premise that the inertial reference frame cannot be found in practice, a logical circularity just exists according to the above definitions[2, 3]. It turns out, as shown in the second section of this article, that such a logically circular definition is entirely avoidable.

For actual reference frames, which are non-inertial(here might be denoted by O), no dynamics equation can be applied directly. Even by a mathematical transformation of Newton's second law[2], we have

$$\begin{aligned} \boldsymbol{F}|_p &= m_p \boldsymbol{a}|_{p-\Sigma} \\ \Rightarrow \boldsymbol{F}|_p &= m_p[\boldsymbol{a}|_{p-O} + \boldsymbol{a}|_{O-\Sigma}] \\ \Leftrightarrow \boldsymbol{F}|_p + (-m_p \boldsymbol{a}|_{O-\Sigma}) &= m_p \boldsymbol{a}|_{p-O}. \end{aligned} \tag{2}$$

In the kinematic part of the above equation, the acceleration is expressed relative to a non-inertial reference frame. But such an expression is not a true formula of dynamics, because the second term on the left-hand side $(-m_p \boldsymbol{a}|_{O-\Sigma})$ is not a real force, which can neither be calculated theoretically like other common forces nor measurable in practice since the inertial reference frame Σ is still required as a premise. As a fictitious force, the definition of inertia force is introduced [2]

$$\boldsymbol{f}|_{inertial} = -m_p \boldsymbol{a}|_{O-\Sigma}. \tag{3}$$

Thus, the equation which simulates Newton's second law for non-inertial reference frames, is obtained.

$$\boldsymbol{F}|_p + \boldsymbol{f}|_{inertial} = m_p \boldsymbol{a}|_{p-O}. \tag{4}$$

It is worth noting that the calculation formula of inertia force still requires finding an inertial reference frame first. Therefore, the above formula does not break through the dilemma that the dynamics equation of Newtonian mechanics is always limited to the non-existent inertial reference frame[3]. In practical application, the kinematical quantity also cannot be measured by referring to the absolute background of the universe[4], so the approximated inertial reference frame must be directly selected for mechanical analysis. If the approximation is insufficient, the magnitude and direction of an inertia force should be further considered.

In the special theory of relativity, the dynamical principle of relativity is extended to the principle of special relativity. That is, all laws of physics (mechanics, electromagnetism, and other interacting dynamical laws) are required to remain the mathematical form invariant in all inertial reference frames. In other words, the scope of the equivalence between reference frames (equal weight) is still limited to the inertial reference frames. Compared with Newtonian mechanics, the scope of application of the dynamical law is not significantly broadened[3].

In the general theory of relativity, Einstein's principle of general relativity is introduced as an axiom. The principle of general relativity is summarized as follows: all reference frames (including translational and rotating reference frames) are equal, that is, an objective and realistic physical law should be established within all physical reference frames with unchanged mathematical forms. Compared with the original inescapable inertial reference frame, the dynamical principle of relativity in Einstein's general theory of relativity is broadened to the greatest extent as a self-evident axiom[3, 5]. As we all know, general covariance is a very important theoretical property of Einstein's general theory of relativity. The principle of general relativity is just the physical basis of general covariance[5] and therefore one of the theoretical cornerstones of Einstein's general theory of relativity. It was the "free-falling elevator" thought experiment that provided Einstein with the inspiration and ideas that led to Einstein's (non-weak) equivalence principle, which states that the inertial force and the gravitational force are physically equivalent. It is Einstein's (non-weak) equivalence principle that gives the principle of general relativity its "conceptual ladder"[3, 5]. However, compared with the principle of Galilean relativity and the principle of special relativity, the principle of general relativity still lacks key theoretical proof and credible evidence.

This paper is devoted to exploring the physics and logic of the principle of relativity for particle dynamics. From the point of view of causal correspondence, the possibility of incorporating the translational and rotating reference frames into the dynamical principle of relativity is discussed. The whole paper is organized as follows. The first part, as an introduction, expounds on the background and development of the principle of relativity. In the second part, the formal logic of Newton's second law is investigated. According to the most

fundamental requirement of causal correspondence, a new particle dynamics equation applicable to any translational reference frame is introduced. The third part reflects on the above successful reformulation of Newton's second law, which fully demonstrates the importance and indispensable role of the reference object in the establishment of particle dynamics equation. The fourth part, combined with the fundamental requirement of causal correspondence for the reference frame, dwells on the mandatory requirement of how to extend the principle of relativity into the rotating reference frame. The fundamental difficulty of such an extension is pointed out. Finally, this paper briefly explains that a moderately generalized principle of relativity can meet the basic requirements of physics.

2 successful reformulation for Newton's second law

The vitality of physical laws lies in their predictability. According to predictability, cause and effect can generally be separated. Therefore, the causal correspondence between the cause and the effect can be regarded as the most fundamental requirement for physical laws[6].

Before we begin to analyze the causal correspondence in the formalism of particle dynamics, actually there is a cognitive problem about reference objects and reference frames, which must be clarified first. Are reference objects and reference frames mathematical or physical? As a useful reference frame in physics, at least its reference origin must be established on the real reference object[2, 3]. This is particularly obvious in the selection of non-inertial frames of reference. Only when the reference object is selected what the non-inertial reference frame is exactly clear. Even for the center-of-mass reference frame, the solid reference object selected by the center-of-mass reference frame is equivalent to all the particles in the whole particles system, but the spatial position of the center-of-mass is redefined and processed mathematically. Therefore, when studying the motion of the center-of-mass relative to the external environment, we must consider the total of external forces exerting on all the particles in the whole particles system. If the center-of-mass reference frame is not boiled down to solid reference objects, there would be no sense of force for the center-of-mass.

Because a physical reference frame has to be found in the real universe, there is a problem with whether it can be found[2]. A mathematical reference frame is a category of definition. When using the ground (or laboratory) reference frame, in fact, any stationary object in the ground (or laboratory) can be selected as the reference object. Acceleration is measured with respect to any point at rest on the ground (or in the laboratory), equivalently, with respect to any object at rest on that point. In this case, the reference object is the object at rest on that point. In principle, the range of the reference object can be arbitrarily determined as long as it can be regarded as a particle. Because when the ground (or laboratory) reference frame is approximated

as an inertial reference frame, the properties such as the mass of the reference object do not matter in the calculation. But there a real object must exist on that point; otherwise, physical measurements such as acceleration cannot be really validated and executable. It is precisely the materialist view that the physics of the reference frame must be attributed to the reference object, and the reference object must be real; then on this, a universal particle dynamics equation can be rigorously derived, as has been shown before according to a fundamental requirement of causal correspondence[7]. But here we are going to demonstrate a more coherent and deeper logic that reflects the irreplaceable physics in the extension of the dynamical principle of relativity.

First, in Newtonian mechanics, the law of causality, which is summarized directly from a large number of classical mechanics experiments and used as the basis for determining the calculation formula of common forces, is not Newton's second law[8], because the exact inertial reference frame has never been found and the total net force required by Newton's second law has never really been fully counted. On the premise that the reference frame is fixed, we usually describe the dynamics of a moving object compared with its previous mechanical state. The newly imposed force and the resulting relative acceleration constitute a causal difference equation between the previous and post states. In this sense, what law of causality is relied upon is an empirical law just described by a difference equation:

$$\Delta \boldsymbol{F} \cong m \Delta \boldsymbol{a}. \tag{5}$$

Here $\Delta \boldsymbol{F}$ represents the new imposed force compared with the previous state, and $\Delta \boldsymbol{a}$ represents the resulting acceleration increment compared with the previous state. Historically, such a difference equation (the differential causality may be expressed as $d\boldsymbol{F} \cong m d\boldsymbol{a}$) has been the basis in the study of the calculation formula for common forces, including gravitational force, friction and elasticity. Once the calculation formula for forces has been summarized from some particular experiments, the dynamics equation can be tested in other general cases. Therefore, particle dynamics is essentially a causal law about force and acceleration, force should be the cause, and acceleration is the effect[6].

Second, there is a necessary procedure that the difference equation ($\Delta \boldsymbol{F} = m\Delta \boldsymbol{a}$) as an empirical law must be raised to a theoretical formula, the force term in the theoretical formula must count all the forces acting on the particle. Because if we don't, every time we apply the formula in a new situation, we don't know which force should be taken into account and which force should not be taken into account.

Third, but when Newton's second law is desired to be applicable in the practical reference frame(O), its theoretical formula should be written down as $\boldsymbol{F}|_p = m_p \boldsymbol{a}|_{p-O}$. Since the force is the cause and the acceleration is the effect, the cause ($\boldsymbol{F}|_p$) depends only on the object being investigated p, and the effect ($\boldsymbol{a}|_{p-O}$) depends both on p and on the reference frame O (in fact, equivalent to depend on the reference object o ,which is defined as the origin of

reference frame). Now, from a different perspective, skip the details of force and acceleration, and only look at the above equation formally (with the specific selection of particle as the variable). It is equivalent to say that there is only one formal variable of cause ($\boldsymbol{F}|_p$): p , while there are two formal variables of effect ($\boldsymbol{a}|_{p-O}$): p and o. However, the measured relative acceleration is determined to vary with o. Therefore, judging from this kind of formal logic, it is obvious that the cause and effect contained in the above Newton's second law do not satisfy the one-to-one correspondence (formal variables are different). This is called causal asymmetry in this article.

The causal asymmetry exists on both sides of the formula of Newton's second law. That is why Newton's second law only applies to the inertial reference frame, which only exists in theory rather than in practice. In other words, if the traditional theoretical formula of Newton's second law is desired to be directly applicable in any practical reference frame, it is not adequate to consider the forces acting on the object under study only, but the forces acting on the reference object should also be considered since any practical reference frame is defined according to the real reference object. It is worth emphasizing that the requirement of causal correspondence is so fundamental that it is not limited to the specific form of particle dynamics; whether classical mechanics or relativistic mechanics, the requirement of causal correspondence should be implemented in general. The actual reference frames are ever-changing in practice, and the actual accelerations relative to the reference frames are also ever-changing. As long as the force corresponds to the cause and the acceleration corresponds to the effect, why do we only need to consider the force acting on the investigated object, but don't consider the force acting on the reference object?

Finally, how to establish the correct theoretical formula based on the causality given by the difference equation($\Delta\boldsymbol{F} \cong m\Delta\boldsymbol{a}$)? The key is to ensure that the force and acceleration of the reference object satisfy the causal symmetry on both sides of the new formula of particle dynamics. The only new physics which should be included may be that, for the first time, the dynamics of the reference frame is properly attributed to the reference object, to which Newton's second law is naturally applied. The complete derivation is presented as follows. At any given moment, the total force acting on a particle under study should be objective and not change with the observer. Therefore, the corresponding result must also be objective, that is, independent of the choice of reference frames. A complete objective acceleration of the particle under study can only be expressed as the acceleration in the background of cosmic space,

$$\boldsymbol{F}|_p = m_p \frac{d^2}{dt^2}\Omega|_p. \tag{6}$$

The background of cosmic space here refers to the void left in the universe after the removal of all evolvable things. The objectivity of the position here simply means that it has nothing to do with any artificial choice made by the human mind. Therefore, the particle's position in the background of cosmic

space is born to be objective since the frame of reference has not been artificially introduced. Here the letter Ω is specially used to indicate the objective position of the particle in the background of cosmic space. This point is exactly analogous to the concept of "event" in the special theory of relativity[9]. The objective position of any particle at any moment actually constitutes an event. Similarly, in the special theory of relativity, any event itself is assumed to have an objective position in the background of space-time so that the coordinate values of the same event can be related in different inertial reference frames. To say the least, at any moment, any particle with an objective position in the background of cosmic space is also a necessary but not sufficient component of Newton's absolute space-time view.

Digging deeper, the fact that a particle or event has an objective position in the background of cosmic space might means that the background of cosmic space is absolute. In order to be compatible with the experiments of relativistic physics, it is necessary to minimize the extent to which the absolute concept exists. The concept of space-time may be further divided into the background of space-time and the scale of space-time. The scale of space-time is actually the length of the basic units of space-time, which is defined by the observer according to the physics phenomena inherent in the natural material world, so it should be affected by some kinds of interactions and could be relative. But the background of space-time reflecting the length of the scale of space-time must be absolute. Because the background of space-time itself is not a specific matter, there is no interaction acting on it. Therefore, the simplest basis of deduction here may indicate that only the background of the cosmic space is absolute.

Although a particle has an objective position in the background of cosmic space, the objective position itself cannot be measured directly. What we can really measure is the difference between two objective positions. Introducing the actual reference object, then it naturally constitutes a mathematical vector:

$$\boldsymbol{r}|_{p-o} = \Omega|_p - \Omega|_o. \tag{7}$$

Thus, we can construct a particle dynamics equation that can be used directly by observers. Any object in the universe should be equivalent in the most basic laws of dynamics. So for the actual reference object o, its dynamics also satisfies,

$$\boldsymbol{F}|_o = m_o \frac{d^2}{dt^2}\Omega|_o. \tag{8}$$

Here the reference object o is defined as the reference origin of a non-rotating reference frame O. Thus a reference frame without rotation relative to the background of cosmic space can be established. The nature of choosing a reference frame is to make a relative measurement of acceleration, and as a causal correspondence, forces should also be relative counted[7],

$$\frac{\boldsymbol{F}|_p}{m_p} - \frac{\boldsymbol{F}|_o}{m_o} = \frac{d^2}{dt^2}[\Omega|_p - \Omega|_o] = \frac{d^2\boldsymbol{r}|_{p-o}}{dt^2} = \boldsymbol{a}|_{p-o} = \boldsymbol{a}|_{p-O}. \tag{9}$$

The acceleration relative to the reference object o is equal to the acceleration relative to the reference frame O. $\boldsymbol{F}|_p$ and $\boldsymbol{F}|_o$ respectively represent the total force acting on the object under study p and the total force acting on the reference object o from the whole universe (but not including the force that has not been transmitted). Obviously, Eq.(9) is applicable to any non-rotating reference frame O(note: here the applicable reference frame must be non-rotating since $\boldsymbol{a}|_{p-o} = \boldsymbol{a}|_{p-O}$). Newton's second law is just a special case of the new particle dynamics equation (9) when the total net force acting on the reference object is zero ($\boldsymbol{F}|_o \equiv 0$). Therefore, strictly speaking, the new particle dynamics equation and Newton's Second law are not equivalent[7]. But the new particle dynamics equation complements an independent term omitted by Newton's second law in the "definite integral" process of their common differential causality ($d\boldsymbol{F} \cong md\boldsymbol{a}$).

In special theory of relativity, the theoretical dynamics equation is $\boldsymbol{f} = d\boldsymbol{p}/dt$, but our reformulation starts from $\boldsymbol{F}|_p = m_p\boldsymbol{a}|_{p-O}$. Why is it reasonable? In fact, the former formula is only more applicable to the case of variable mass than the latter. The essence of the variable mass problem in the classical low-speed case (such as the rocket launching problem) can be attributed to the separation and relative motion between particles in a particles system[2], rather than the issue of dynamics of a single particle. Thus, the fundamental equation for particle dynamics in Newtonian mechanics is still $\boldsymbol{F}|_p = m_p\boldsymbol{a}|_{p-O}$, and $\boldsymbol{f}|_p = d\boldsymbol{p}|_{p-O}/dt$ can be regarded as an effective form introduced when the single particle dynamics is extended to the particles system. As for the special theory of relativity, the relativistic form of particle dynamics $\boldsymbol{f}|_p = d\boldsymbol{p}|_{p-O}/dt$ is favored, because the mass of particle can change, and its physical origin can be attributed to the principle of constant speed of light. But in fact, even in relativistic mechanics[9], the real basic starting point is $F_\mu = m_0 d^2x_\mu/d\tau^2$. Only in a specific reference frame, the relativistic form $\boldsymbol{f}|_p = d\boldsymbol{p}|_{p-O}/dt$ is thus derived from this starting point.

3 Application example of the generalized dynamics equation

We take a three-body system including the Sun(S), the Earth(E) and the Moon(M) as an example to illustrate the practical advantage of the generalized dynamics equation (9). The dynamics of the Moon with respect to the Earth is addressed. Since the geocentric reference frame is not exactly inertial, the dynamical equation is given by Newtonian mechanics (4)

$$\boldsymbol{F}|_{_M} + \boldsymbol{f}|_{inertial} = m_{_M}\boldsymbol{a}|_{_{M-E}}. \tag{10}$$

However, to solve the dynamics of the Moon in the geocentric reference frame, an inertial frame of reference must be introduced first. Because the investigated system is an ideal system only including the Sun, the Earth and the Moon, there is no substantial object that can be approximated to establish an inertial frame of reference to a high degree. In principle, a direct application of equation

(10) is difficult. However, in order to show the influence on the calculation accuracy brought by the approximation of the inertial reference frame, it is assumed that the heliocentric reference frame can be approximated as the inertial reference frame. Therefore, in the heliocentric reference frame, the inertial force is approximated as

$$\boldsymbol{f}|_{inertial} \approx -m_{_M}\boldsymbol{a}|_{_{E-S}}. \tag{11}$$

The degree of approximation of the selected heliocentric reference frame will directly determine the accuracy in solving dynamics equation (10) in practice. The higher the actual reference frame is approximated to the inertial reference frame, the higher the calculation precision will be. Then, to calculate $\boldsymbol{a}|_{_{E-S}}$ accurately, we need to measure the acceleration of the Earth relative to the Sun. If we expect to do this mathematically by reversing the process to theoretically solve $\boldsymbol{a}|_{_{E-S}}$, we will get stuck in the same cycle as when we started to calculate $\boldsymbol{a}|_{_{M-E}}$.

Here, the heliocentric reference frame can be approximated again as an inertia reference frame. So the acceleration of the Earth relative to the Sun numerically satisfies Newton's second law as an approximation :

$$\boldsymbol{F}|_{_E} \approx m_{_E}\boldsymbol{a}|_{_{E-S}}. \tag{12}$$

So far, in the application of Equation (10) under the traditional approach, it has been superimposed with two approximations at the theoretical stage, rather than the actual measurement or statistical stage.

In contrast, the generalized dynamics equation (9) is directly applied, then

$$\frac{\boldsymbol{F}|_{_M}}{m_{_M}} - \frac{\boldsymbol{F}|_{_E}}{m_{_E}} = \boldsymbol{a}|_{_{M-E}}. \tag{13}$$

Because the discussion is limited to the ideal three-body system, the forces acting on the Moon and the Earth can be calculated, respectively, according to the law of gravity.

$$\boldsymbol{F}|_{_M} = G\frac{m_{_M}m_{_E}}{r^3_{_{M-E}}}\boldsymbol{r}|_{_{M-E}} + G\frac{m_{_M}m_{_S}}{r^3_{_{M-S}}}\boldsymbol{r}|_{_{M-S}}, \tag{14}$$

$$\boldsymbol{F}|_{_E} = G\frac{m_{_E}m_{_M}}{r^3_{_{E-M}}}\boldsymbol{r}|_{_{E-M}} + G\frac{m_{_E}m_{_S}}{r^3_{_{E-S}}}\boldsymbol{r}|_{_{E-S}}. \tag{15}$$

Substituting back the above theoretical expression of the force, equation (13) can be directly solved. It's not hard to verify that the inertial force in (10) is exactly expressed,

$$\boldsymbol{f}|_{inertial} = -\frac{m_{_M}}{m_{_E}}\boldsymbol{F}|_{_E}. \tag{16}$$

By comparing (16) with (11), it can be found that no approximation is used in the application of the generalized dynamics equation (9). The expression (16) for the inertia force is accurate here. While in the traditional approach of

formula (10), the real calculation of inertia force inevitably requires approximation. The application of the generalized dynamics equation (9) eliminates the approximation and avoids the resulting error in precision.

Interestingly enough, in the traditional approach, the obtained expression for inertial force will return to the exact expression (16) if and only if the inertial reference frames are approximated twice to the same extent(see (12) substituted back into (11))! In fact, the twice approximations of inertial reference frames of the same degree perfectly offset the error caused by the approximation itself. And this exact cancellation is actually independent of the degree of approximation. That is to say, it is independent of what kind of actual reference frame is chosen to approximate the inertial reference frame. This shows that under the standard framework of Newtonian mechanics, if the approach in the non-inertial reference frame is still dependent on the concept of the inertial reference frame, it is essentially running circles. However, the application of the generalized dynamics equation (9) has got the essence of physics.

In a word, our reformulation of the particle dynamics equation is successful, and the idea of extending the principle of relativity from inertia reference frames to translational reference frames is correct.

4 causal correspondence and indispensable reference object

In fact, in Newton's second law for the reference frame, only its state of motion is considered. But the force acting on the reference object has been ignored[10–12]. It causes Newton's second law to hold in theory only in inertial frames of reference, but no strict inertial reference frame can be found in practice.

Maybe someone looked back at the application of traditional Newton's second law, and the reference object didn't seem to be necessary to the reference frame itself. Actually, it's not the truth. As long as it is a real physical application, the reference object must be used, otherwise, it is impossible to define the origin point of the reference frame. This is particularly obvious in the selection of non-inertial frames of reference. Only when the reference object is selected what the non-inertial reference frame is exactly clear. However, in the selection of the ground and laboratory reference frame, this point is very hidden and seems to be never related to the specific reference object. A fundamental reason is that here the ground or laboratory reference frame has been approximated as an inertial reference frame, so the force acting on the reference object, which corresponds to the inertial force, is ignored from the generalized dynamics equation. But in practice, even if the force acting on the reference object is ignored, the acceleration of the object under study must still be measured relative to the actual reference frame. Otherwise, there will be no problem how with finding an inertial reference frame.

In fact, if the generalized dynamics equation (9) takes a special case:

$$\boldsymbol{F}|_o = 0, \tag{17}$$

which just means that the total force acting on the reference object equals zero, the formula (9) goes back to Newton's second law. Therefore, Newton's second law can definitely be derived from the generalized dynamics equation (9). But not vice versa, because in the derivation of the generalized dynamics equation, actually there is a new physics has been added. The dynamics of the practical reference frame is completely attributed to the reference object, and the reference object is also completely placed on an equal status with the object under study.

Compared with the Newtonian era, people at that time were easily bound by ideas such as "geocentric theory" or "heliocentric theory", and even Einstein had the idea of a steady-state universe at the beginning. On the one hand, this has led to people depending on the idea of an absolute inertial reference frame for a long time without reconstructing the dynamics equation directly from the non-inertial reference frame. On the other hand, it is precisely because of the preconceived concept of an inertial reference frame that people tend to only consider the kinematical properties of the actual reference frame relative to the inertial reference frame and do not further consider the force acting on its reference object.

The reference object is indispensable to describe the particle dynamics. In the spirit of causal correspondence, no matter what the specific form of particle dynamics is, whether relativistic or non-relativistic, as long as the force acting on the reference object does not appear in the formula of particle dynamics, the dynamics equation cannot be really generalized into the actual reference frame.

5 Mandatory requirements from rotating reference frames

First, from a physical point of view, the basis of the principle of general relativity is investigated. Compared with Newton's second law (1), the second term of the equation (9) is explicitly added, which just explains the extra term introduced by the transformation of reference frames for Newton's second law — inertia force. By comparing the equation (9) with the equation (4), the physics nature of the inertial force originated from the form of Newton's second law is expressed as[7]

$$\boldsymbol{f}|_{inertial} = -\frac{m_p}{m_o}\boldsymbol{F}|_o. \tag{18}$$

It can be seen that the nature of inertia force is the mass-ratio weighted real force acting on the reference object, which can be gravity or other common forces. More importantly, this force is not applied to the object under study, but to the reference object. Because the concept of inertial force [3, 13] is rooted in the form of Newton's second law, therefore to fundamentally solve

the problem of inertia force, the best and most thorough way is to find the exact equivalent correspondence or physics substitution under the exact same framework. Given the above explicit explanation, the nature of inertial forces is proved to be not physically equivalent to the gravitational force. Therefore, Einstein's principle of general relativity, which is just based on the equivalence principle[5, 13, 14], is now provided solid evidence to the contrary.

Second, from a mathematical point of view, whether the particle dynamics is able to keep invariant under the rotational transformation between reference frames, can be analyzed qualitatively according to the fundamental requirement of causal correspondence. It is well known that for the physical reference frame attached to a rotating rigid body, at least four non-coplanar reference particles fixed on this rigid body are needed to determine all kinematics properties for the rotating rigid reference frame. Therefore, when constructing the formula of dynamics, if a physical rotating reference frame is selected, the formula of dynamics must theoretically include at least four non-coplanar reference particles' kinematical information and exerted forces at the same time to keep the causal symmetry on both sides of the formula of dynamics. This is very difficult and needs to be further studied, but at least it has not been achieved under the current framework of mathematical physics. Moreover, in order to investigate one moving particle in a rotating reference frame, the formula of dynamics must therefore introduce four non-coplanar reference particles simultaneously, which is also extremely uneconomical in metaphysics. Finally, it is suggested that the principle of physical relativity for particle dynamics should be generalized to all of the translational reference frames. For the rotational part, the rotating reference frame can be used in principle, but it should make a coordinate transformation at first into the adjoint translational reference frame, and then the new generalized dynamics equation is applicable.

Based on the above analysis in terms of physics and mathematics, we propose that Einstein's principle of general relativity is not credible.

6 Conclusions

This paper is devoted to the practical applicability of particle dynamics. Therefore the hypothetical reference frame in mathematics is not included in our discussion. Because in principle the dynamics in this kind of imaginary reference frame can be obtained by making a mathematical transformation based on the realistic dynamics in an actual reference frame. Therefore, it is the invariance in the physical reference frame, rather than the mathematical reference frame, that is most urgently needed to be addressed and must be addressed. As for the relation between the reference object and the reference frame, if the reference object is first assigned in a specific problem, the reference frame can be established naturally with the reference object as the reference origin. If the reference frame is assigned first, then in principle any actual object fixed

in the reference frame can be regarded as a reference object. The most conventional ground reference frame, for example, is actually selecting any object fixed to the ground as a reference object.

Practically speaking, any reference object we can find to an actual reference frame is in perpetual motion in the universe, but we can never be sure of the exact position or velocity of this reference object(including the observer's Earth) in the universe. Although any object can use very distant galaxies to determine the rotation relative to the universe, for the dynamics, the ideal solution is, as long as the reference objects are selected, people can completely determine the movement of any object relative to the reference object according to the forces acting on the object, without having to change the mathematical formula for dynamics, This is the basic spirit of the dynamical principle of relativity [3, 13, 14].

According to the discussion in this article, the new generalized dynamics equation (9) keeps the formula invariant under arbitrary transformation between translational reference frames. Compared with the Galilean mechanical principle of relativity based on the inertial reference frame and the principle of general relativity based on arbitrary reference frames[3, 13, 14], the invariance for arbitrary translational reference frame is between them and has been proved in the logical derivation of the new generalized dynamics equation[7]. Therefore, the form invariance based on the translational reference frame shown in the new generalized dynamics equation (9) can be called a principle of moderate relativity.

As the first demonstration of the nature of inertia force by the new generalized dynamics equation, the equation (18) clearly does not support Einstein's principle of general relativity. According to the basic spirit of causal symmetry for particle dynamics, no matter what the specific form of particle dynamics is, whether relativistic or non-relativistic, as long as the force acting on the reference object does not appear in the form of the dynamics equation, the dynamics equation cannot be generalized to the actual reference frames. Moreover, if the dynamical principle of relativity is to be further generalized into the rotating reference frame, it is necessary to include at least four reference particles' kinematics and forces simultaneously on both sides of the dynamics equation. It has not been explicitly achieved in the existing mathematical physics and needs further exploration. Therefore, any generalization of the principle of relativity to rotating reference frames for particle dynamics needs to be carefully treated and verified. To say the least, Einstein's principle of general relativity is not credible.

In fact, the principle of moderate relativity can meet the basic needs of practical observation and application. On the one hand, we can never be sure of the exact position, the velocity of the observer's Earth in the background of the universe. As for the acceleration of the reference frame with respect to the background of the universe, it can be distinguished in principle but is difficult to be determined. In other words, the translation of the reference frame with respect to the background of the universe should not be categorically

distinguished. On the other hand, due to the eternity and invariability of the background of the universe, we can always determine the rotation of any reference frame with respect to the background of the universe by means of the sufficiently distant galaxies. In practice, since the background of the universe is objective, the direction in the background is also objective, and we can define the direction in the background with the help of galaxies far enough away. Therefore, for any reference object, we can define the orientation of coordinate axes according to the direction in the background of the universe and on this basis establish a reference frame without rotating. In other words, the rotational motion of the reference frame can be distinguished in principle. Thus the dynamics law that is really necessary for observers is to keep the form invariant in any non-rotating reference frame. Furthermore, for particle dynamics, any translational phenomena can always be attributed to the motion of a single particle, and any single particle has no concept of rotation. Any reference object, as long as it can be treated as a particle, has no issue with rotation. Therefore, the issue of rotation for reference frame can in essence be technically attributed to a mathematical problem, which can be separated from the physics of dynamical relativity in principle. The simplest and most useful principle of relativity should be keeping dynamics laws invariant with respect to any translational reference frame.

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